

**Docket No. SA-537**

**Exhibit No. 14-D**

**NATIONAL TRANSPORTATION SAFETY BOARD**

**Washington, D.C.**

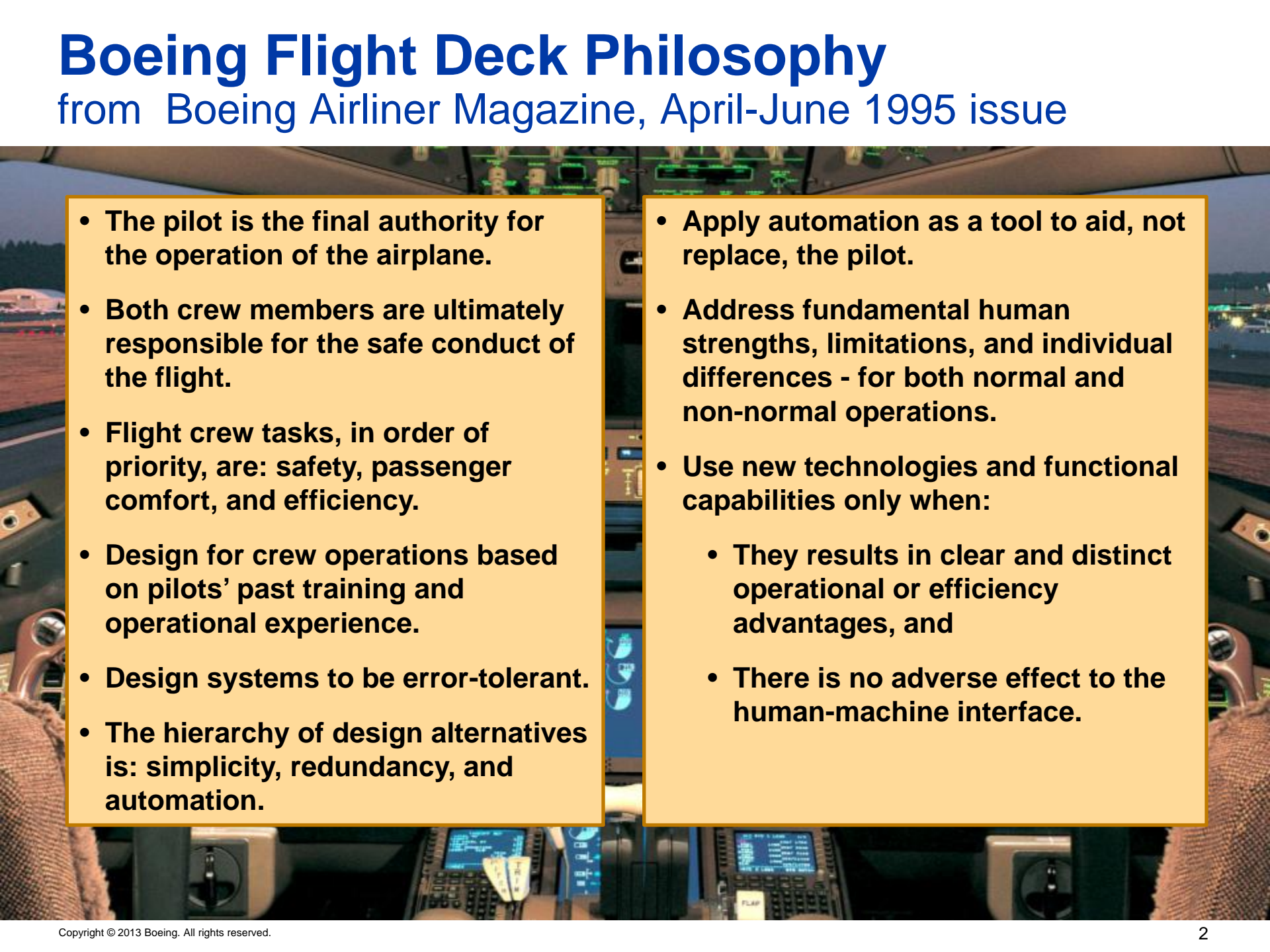
Boeing Material Requested by NTSB

(28 Pages)



# Boeing Flight Deck Philosophy

from Boeing Airliner Magazine, April-June 1995 issue

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- The pilot is the final authority for the operation of the airplane.
  - Both crew members are ultimately responsible for the safe conduct of the flight.
  - Flight crew tasks, in order of priority, are: safety, passenger comfort, and efficiency.
  - Design for crew operations based on pilots' past training and operational experience.
  - Design systems to be error-tolerant.
  - The hierarchy of design alternatives is: simplicity, redundancy, and automation.
  - Apply automation as a tool to aid, not replace, the pilot.
  - Address fundamental human strengths, limitations, and individual differences - for both normal and non-normal operations.
  - Use new technologies and functional capabilities only when:
    - They results in clear and distinct operational or efficiency advantages, and
    - There is no adverse effect to the human-machine interface.

# 777 Flight Deck



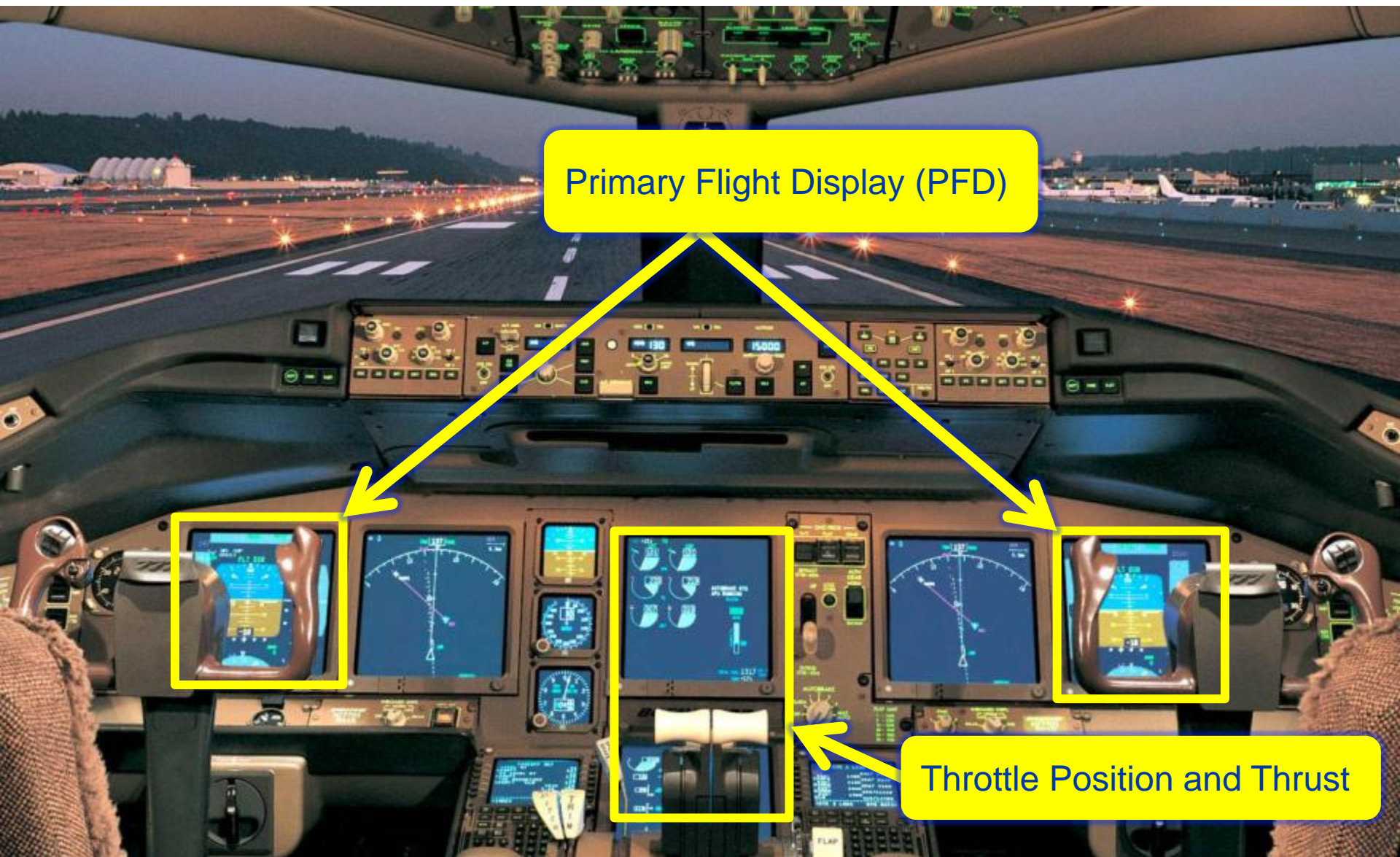


# 777 Flight Deck





# 777 Flight Deck



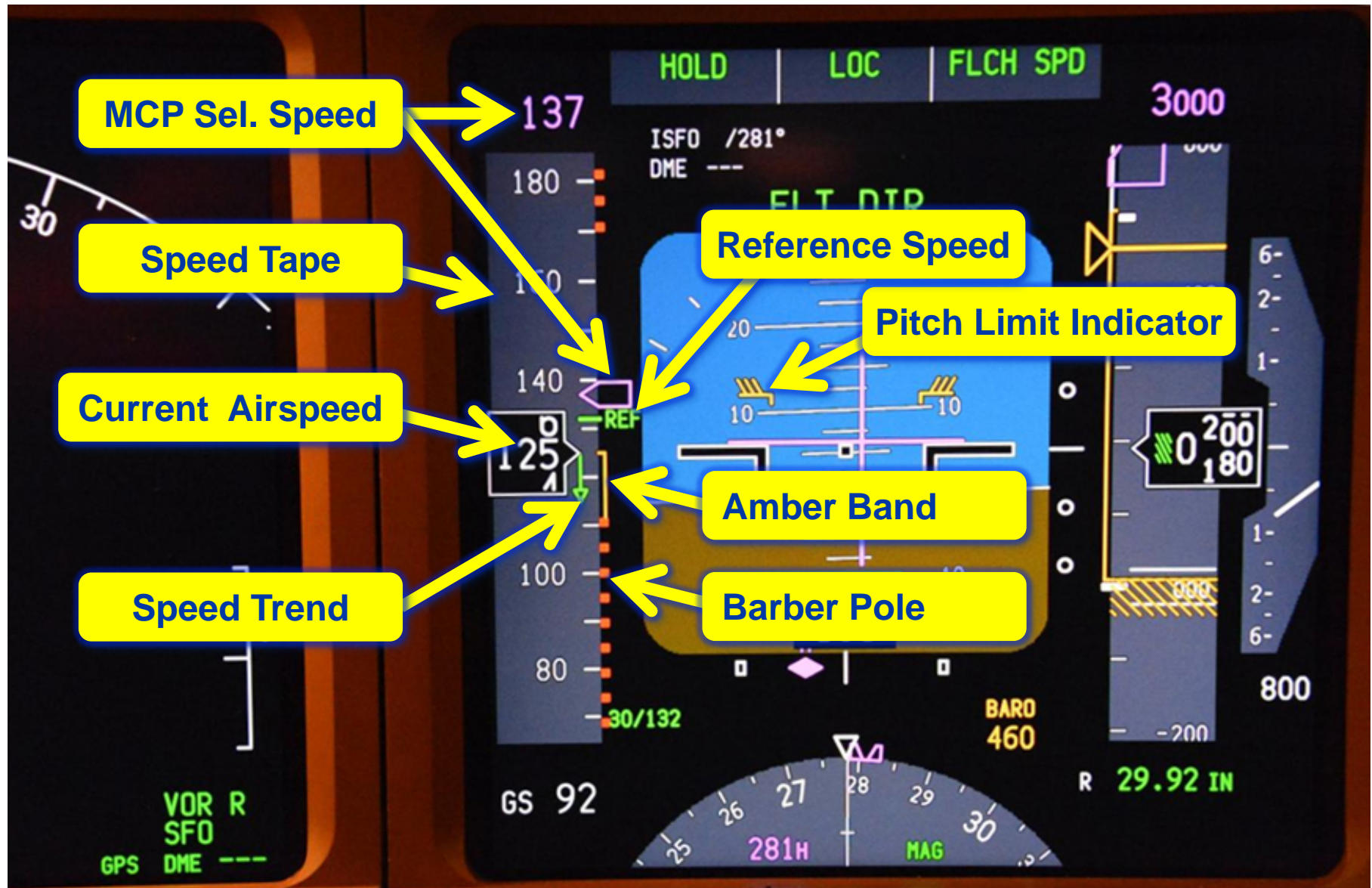
# 777 Primary Flight Display





# Airspeed

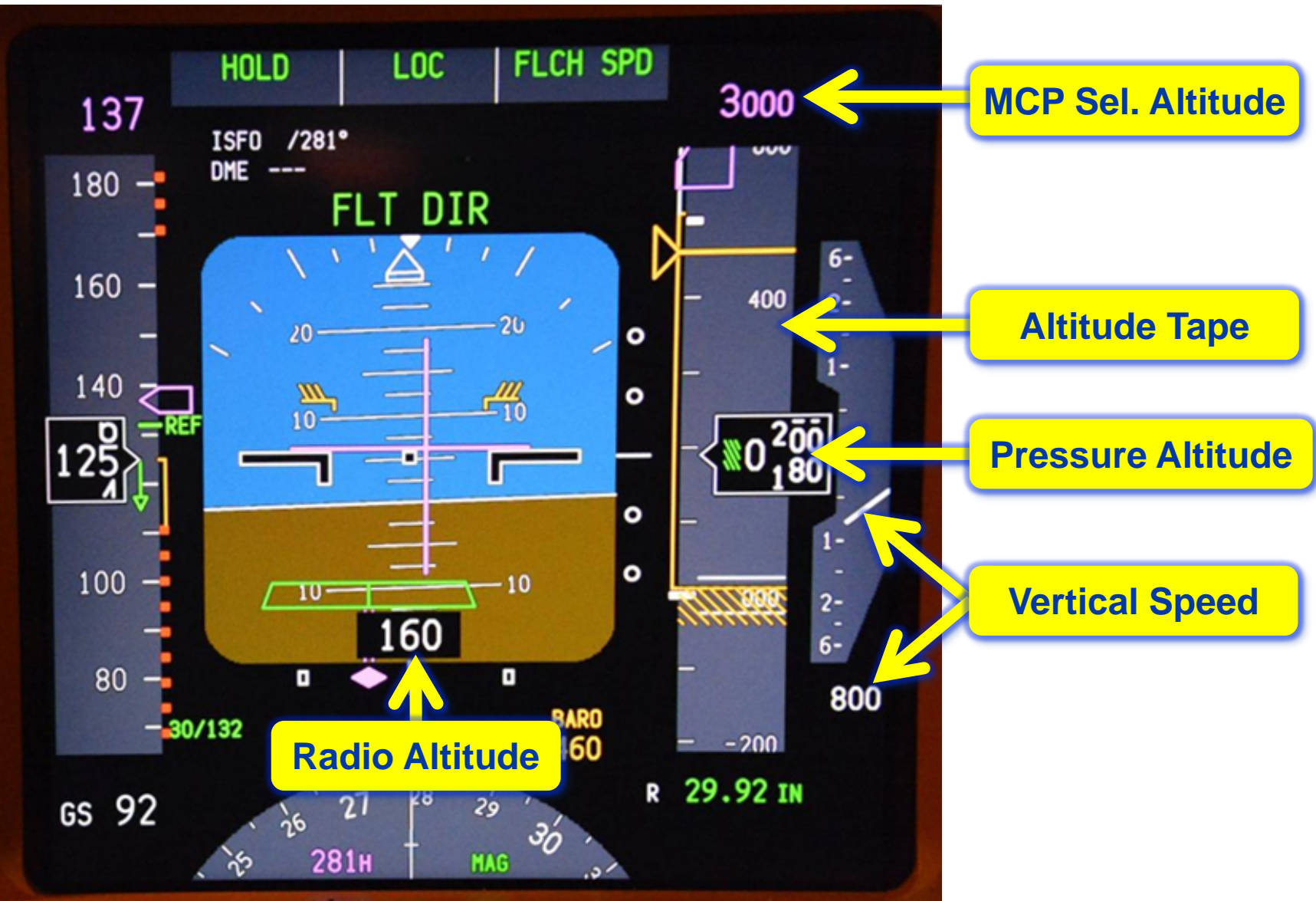
## 777 Primary Flight Display



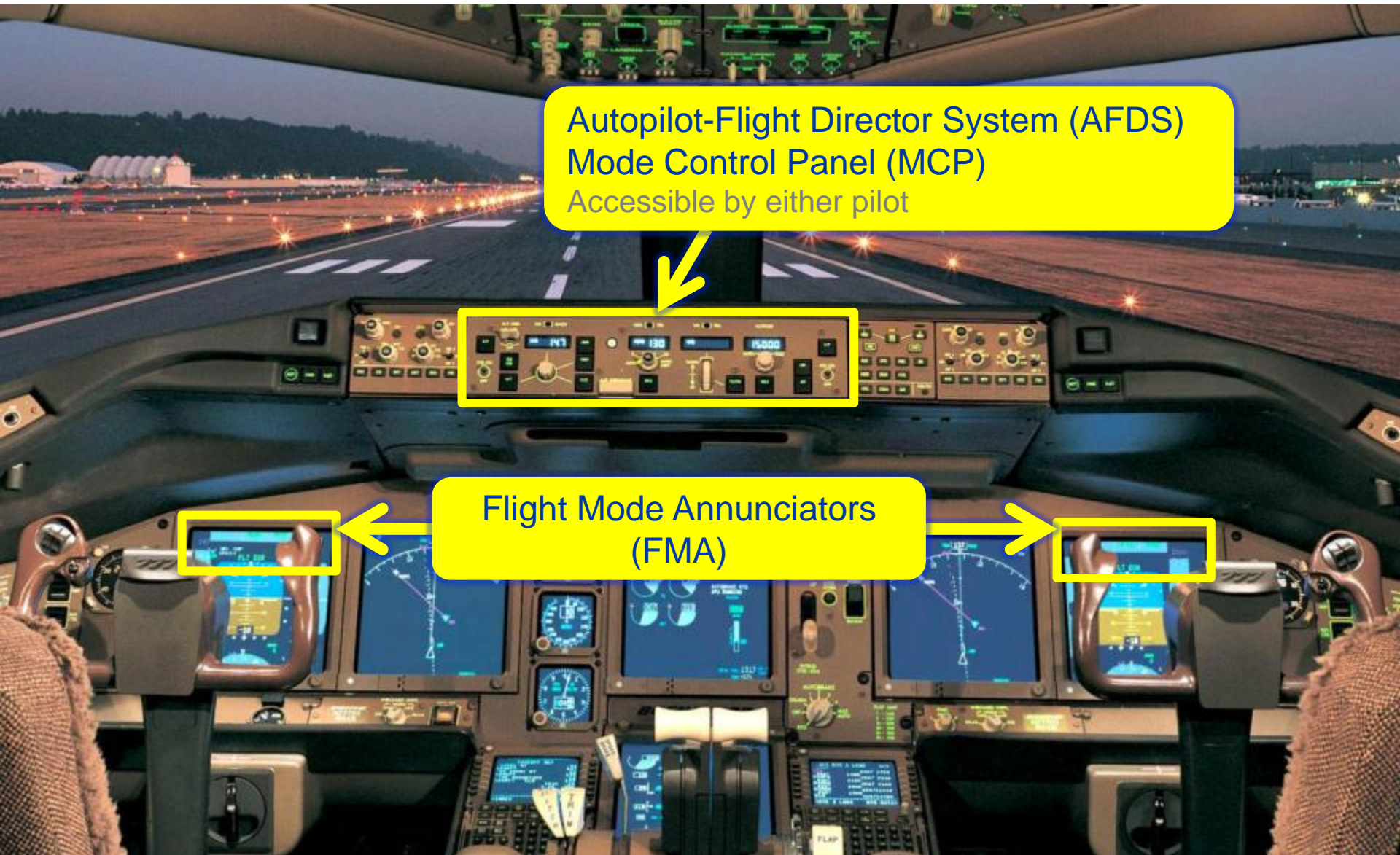


# Altitude

## 777 Primary Flight Display



# 777 Flight Deck





# Mode Control Panel (MCP)

MCP Selected  
Airspeed

Flight Level Change  
- FLCH -

MCP Selected  
Altitude



Autothrottle  
Mode

Roll  
Mode

Pitch  
Mode



Autopilot  
Status

## Flight Mode Annunciator (FMA)

# 777 Flight and Throttle Controls – Interlinked and Backdriven

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- 777 flight controls and throttles are backdriven and interlinked to continuously keep pilots in the loop
  - All pilot flight controls move in unison, whether commanded by a pilot or an autoflight system
  - Thrust levers driven by autothrottle
  - Allows pilots to see and feel how the autoflight systems are flying the aircraft and applying thrust
  - Also allows a pilot to see and feel how the other pilot is flying



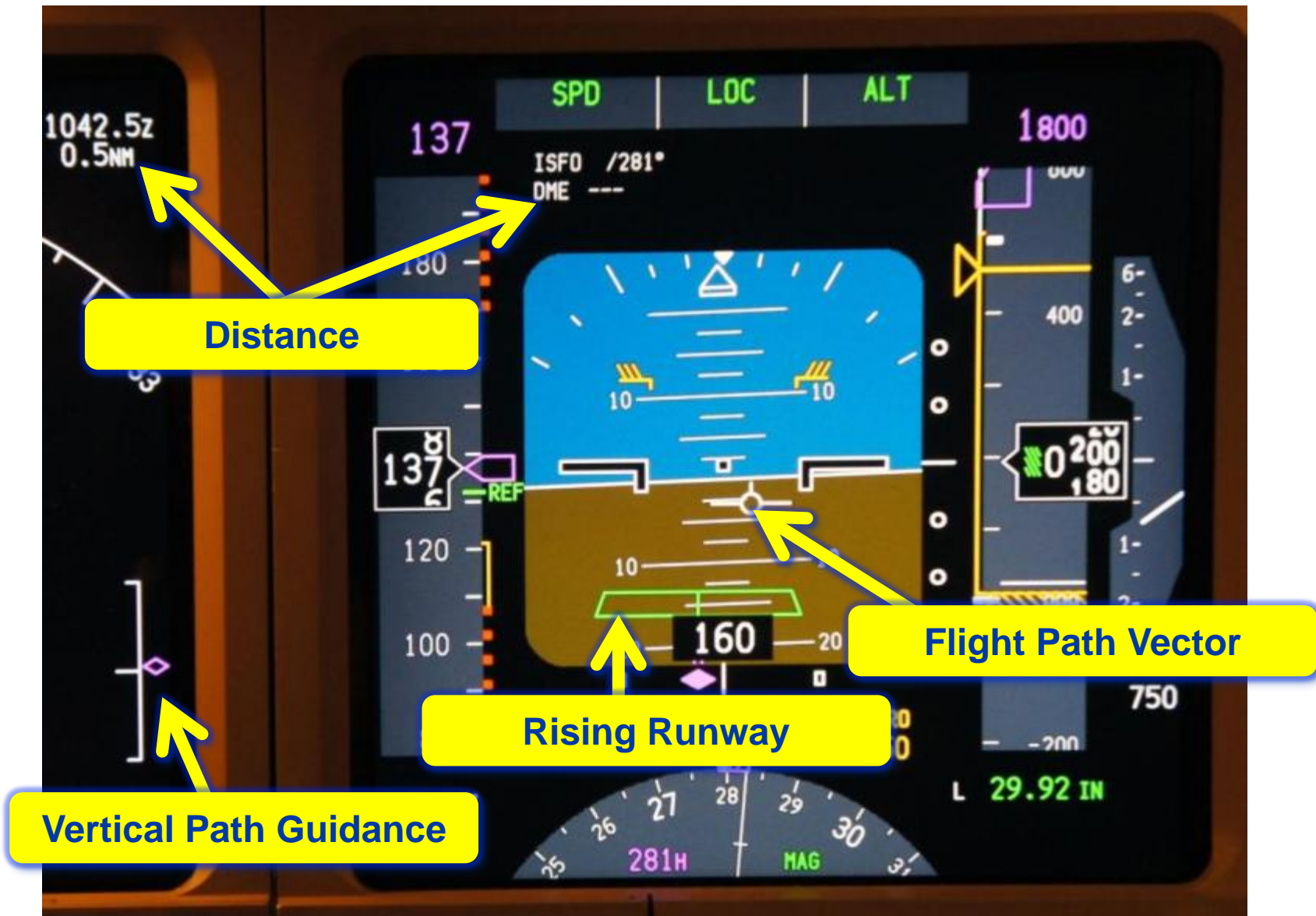


# Expected Use of AFDS/AT During Visual Approach

- Pilot selects level of automation
- Various automation modes – autoflight to hand flying
- AT recommended
- FCOM options

# Additional Vertical Guidance

## 777 Primary Flight Display





# Autopilot & Thrust Management Systems

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- Autopilot Flight Director System (AFDS) provides:
  - Autopilot (AP) pitch, roll and yaw commands to the Primary Flight Control System (PFCS).
  - Flight Director (F/D) guidance for pitch and roll commands on the Primary Flight Display (PFD).
- The Thrust Management Function provides:
  - Referred to as the Autothrottle (A/T)
  - Automatic control of thrust via the Throttle Levers
  - Thrust equalization
  - Thrust Rating / Limit computations

# Autopilot & Autothrottle Pairing

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- Speed can be controlled by Autopilot OR Autothrottle
  - Speed On Elevator** – AFDS controlling speed via Pitch Commands.
  - Speed On Throttle** – Autothrottle controlling speed via Thrust Levers.
- Both systems cannot control speed at the same time
- Autopilot mode is set first,  
then Autothrottle pairs with compatible mode.
- Autothrottle controls speed only in SPD mode.

# History of Use of FLCH & HOLD modes

Model	Year	Number Delivered	Total Flight Hours	Total Landings
757	1982	1050	57.9 M	22.8 M
767	1982	1059	63.4 M	17.8 M
747-400	1989	694	47.4 M	7.5 M
777	1995	1147	38.5 M	7.4 M
747-8	2011	57	0.23 M	0.04 M
787	2011	98	0.14 M	0.05 M
Total	31 Years	4105	207.6 M	55.6 M

- Data as of Mid-2013



# 777 Flight Deck



Engine Indication & Crew Alerting System (EICAS)

# 777 Centralized Crew Alerting

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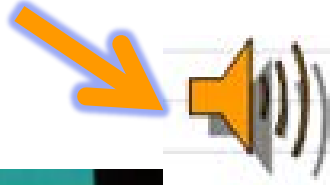
- Single, central location to view all alerts
- Alerts that require immediate action or awareness can be heard and seen (stimulate two senses)
- Alert hierarchy based on priority level:

Alert	Crew Awareness & Action	Color	Aural
Warning	Immediate crew <u>action required</u>	Red	Continuous
Caution	Immediate crew <u>awareness</u> , action may be required	Amber	Tone
Advisory	Routine pilot awareness	Amber	none

- “AIRSPEED LOW” is Caution Level alert
- “Working Together” reviews of the 777 flight deck design

# “AIRSPEED LOW” Caution Level Alert

## 777 Flight Simulator



Quadruple Chime Aural



**AIRSPEED LOW**



# AIRSPEED LOW Alert

## 777 Primary Flight Display

Amber Box



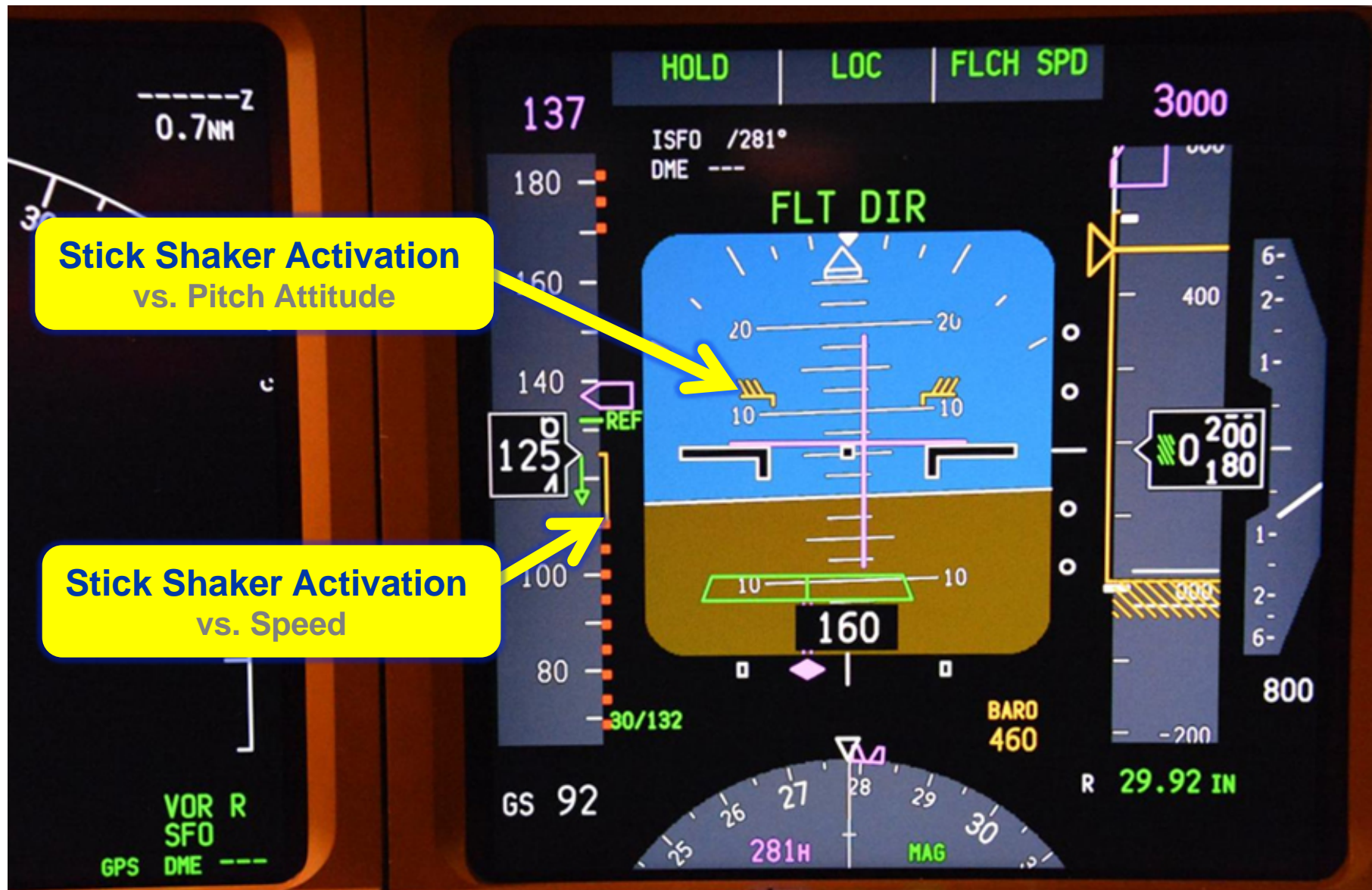
# AIRSPEED LOW - Caution Level Alert

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- Provides pilot awareness of a significant speed error
- Adds a second layer of alerting for significant speed errors
  - “AIRSPEED LOW” Caution occurs before the Stick Shaker Warning
- Alert trigger point (30% into amber band) chosen to be:
  - High enough to provide awareness for pilot to take action to minimize the potential for stick shaker activation
  - Low enough to minimize nuisance trips. Allows operations near the top of amber band

# Stick Shaker Activation

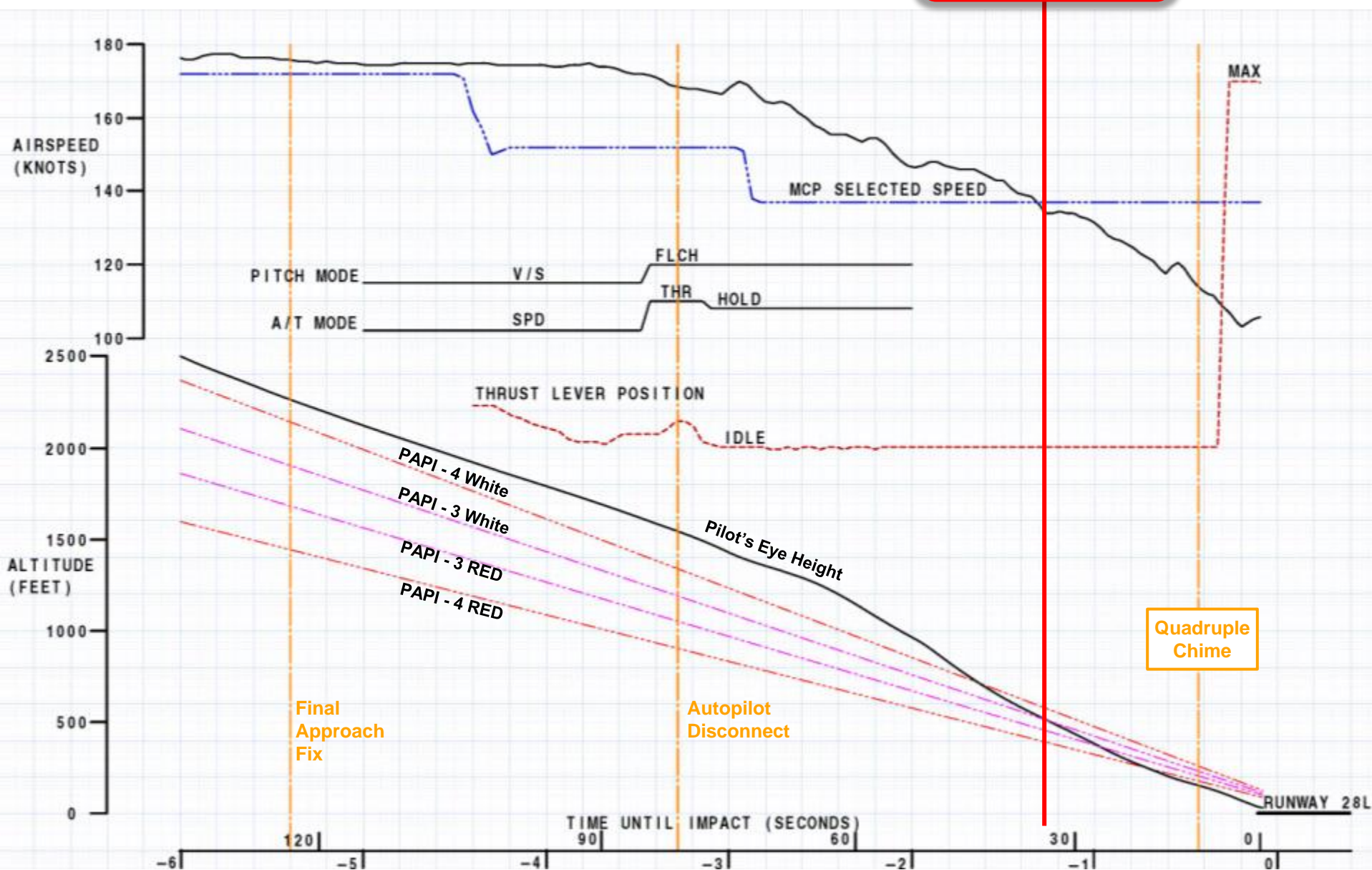
## 777 Primary Flight Display



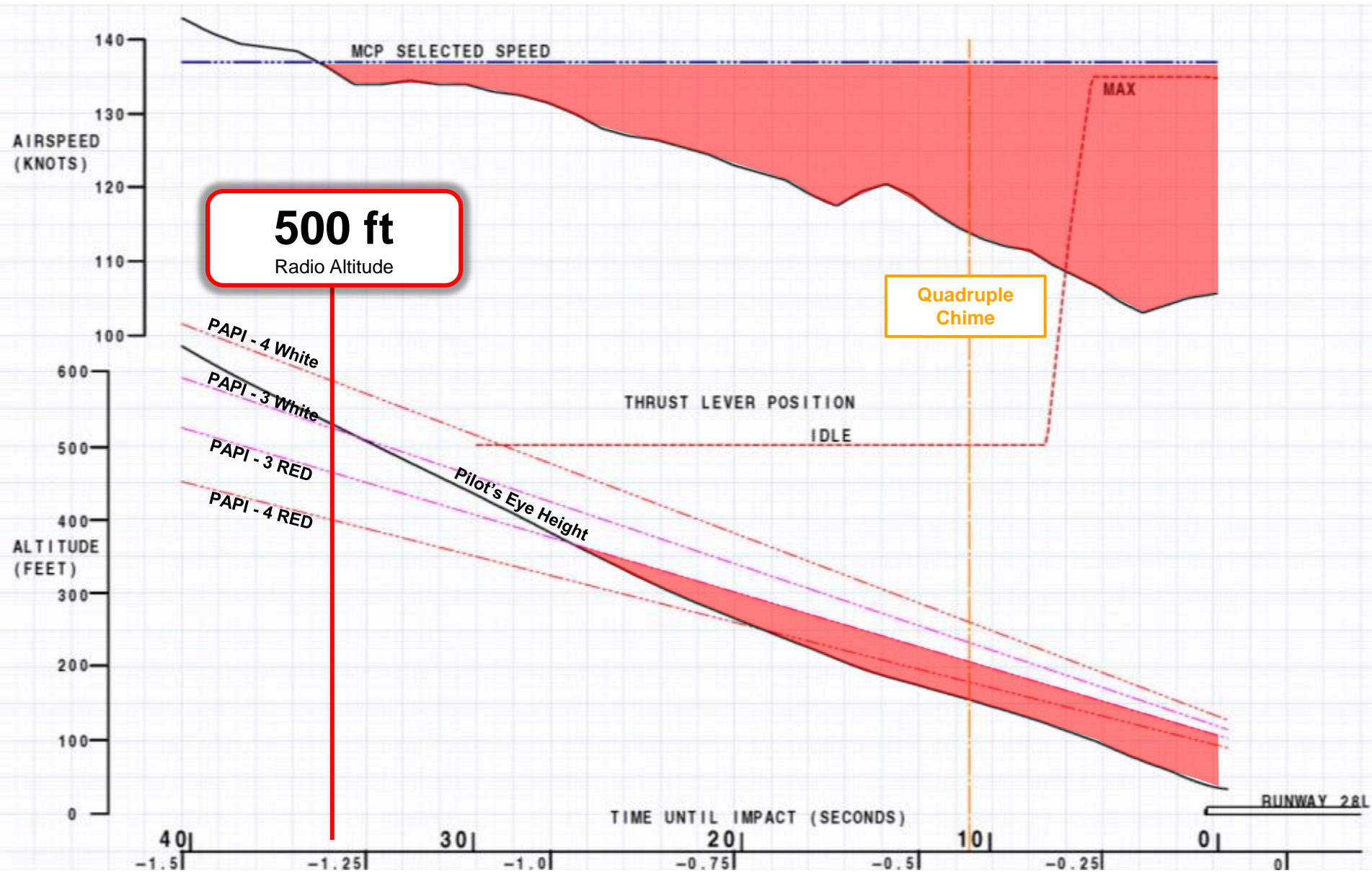


# 500 ft

Radio Altitude



## 34 Seconds



# Stabilized Approach Criteria

HL7742 accident approach versus criteria

Stabilized Approach Criteria	Radio Altitude				
	500 ft	400 ft	300 ft	200 ft	100 ft
Time to Impact (seconds)	-34	-29	-24	-17	-7
Thrust setting is appropriate	Idle	Idle	Idle	Idle	Idle
Sink rate less than 1,000 FPM	-1170	-1120	-1080	-830	-610
Airspeed ( $V_{APP}$ -5 kt, +10 kt) MCP Sel. Speed = $V_{APP}$ = 137 kt	-0 kt decelerating	-3 kt decelerating	-9 kt decelerating	-16 kt decelerating	-25 kt decelerating
On correct path (PAPI)	1 Red	2 Red	3 Red	4 Red	4 Red
Small changes in Heading & Pitch	yes	yes	pitch	pitch	pitch
Correct landing configuration	yes	yes	yes	yes	yes
All briefings & checklists complete	yes	yes	yes	yes	Yes



= does not meet criteria



# Automation Sequence

## Asiana 777 at SFO

1850 ft  
Flaps 20 selected  
MCP Speed to 152



1550 ft  
FLCH Pushed  
A/T to THRUST



1500 ft  
AP Disconnected



1450 ft  
A/T Moved to HOLD



1330 ft  
Flaps 30 selected  
MCP Speed to 137



# Nomenclature

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**AFDS** - Autopilot Flight Director System

**AP** - Autopilot

**F/D** - Flight Director

**AT** - Autothrottle

**EICAS** - Engine Indicating and Crew Alerting System

**FLCH** - Flight Level Change

**MCP** - Mode Control Panel

**Speed On Elevator** - AFDS controls speed via Pitch Commands.

**Speed On Throttle** - Autothrottle controls speed via Thrust Levers.

